DRAFT
WORK ZONE AIR SAMPLING AND MONITORING REPORT FOR REMOVAL ACTION OVERSIGHT WESTERN MINERAL PRODUCTS GLUEK PARK SITE – PHASE II MINNEAPOLIS, HENNEPIN COUNTY, MINNESOTA

SITE ID: B5P2
NPL STATUS: NON-NPL
TDD: S05-0003-0609-038

Prepared for

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Region V
Emergency Response Branch
77 West Jackson Boulevard
Chicago, Illinois 60604

Prepared by

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Date Prepared	March 29, 2007
TDD Number	S05-0003-0609-001
Document Control Number	038-2A-AAGV
Site-Specific ID Number	B5P2
Contract Number	EP-S5-06-04
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ATTACHMENTS

LIST OF ACRONYMS AND ABBREVIATIONS

AHERA	Asbestos Hazard Emergency Response Act
AQO	Air quality objective
CFR	Code of Federal Regulations
ERRS	Emergency and Rapid Response Services
ERT	Environmental Response Team
EX	Excavation Air Sample
HHID	Household Identification
L/min	liters per minute
mph	miles per hour
µm	micron or micrometer
S/cc	structures per cubic centimeter
SOP	Standard Operating Procedure
START	Superfund Technical Assessment and Response Team
STAT	STAT Analysis Corporation
TEM	Transmission Electron Microscopy
VAC	Vacuuming Air Sample
U.S. EPA	United States Environmental Protection Agency
WESTON	Weston Solutions, Inc.
WMP	Western Mineral Products

1. INTRODUCTION

The United States Environmental Protection Agency (U.S. EPA) tasked the Weston Solutions, Inc. (WESTON®) Superfund Technical Assessment and Response Team (START) with performing oversight and asbestos air monitoring for the continued Phase II removal action (removal action) at the Western Mineral Products (WMP) Industrial sites, located in Minneapolis, Minnesota. This removal action was initiated to mitigate the threats posed by asbestos contaminated soil present at the WMP Industrial Facility and surrounding residential properties. The Emergency and Rapid Response Services (ERRS) contractor was Earthtech. The ERRS contractor was responsible for the management and performance of excavation and restoration activities conducted at the properties.

Generally, the WMP Industrial sites targeted were residential properties surrounding the WMP Industrial Facility that had localized areas of asbestos soil contamination, as identified through visual inspection and confirmed through laboratory analysis of surface soil samples. Most cleanup properties were identified within a 0.5-mile radius of the WMP Industrial Facility; however, cleanup properties were identified as far as 30 miles from the WMP Industrial Facility.

During the summers of 2005 and 2006, two target sites were addressed including a Park owned by the Minneapolis Park District and one residential property. Removal activities at park, formally known as Gluek Park (hereafter referred to as Household ID [HHID] #322), were completed throughout both summers, while the removal activities at the residential property (HHID #817) were only completed during the summer of 2005. This Work Zone Air Sampling and Monitoring Report details the sampling process design, sampling methodologies, sample ID system, and sample documentation completed during this removal action. Brief summaries of analytical results and conclusions are also included within this report.

2. SAMPLING PROCESS DESIGN

Air monitoring consisted of air sampling at the two target properties during the 2006 removal action which was completed to confirm the effectiveness of dust control measures conducted during excavation and truck loading activities. Another purpose of air sampling was to assess the actual or potential exposure pathways as indicated in the Conceptual Site Exposure Model (Attachment A) as compared to the site specific air quality objective (AQO) structures per cubic centimeter (S/cc). Results of air sampling were used to identify the type and amount of airborne asbestos fibers generated during the removal action. Air sampling locations were located at the perimeter of excavation. The placement, number, and frequency of air samples collected during excavation activities was determined at the discretion of the U.S. EPA START member in accordance with the procedures set forth in the Environmental Sampling for Asbestos - Work Zone Air Sampling in Residential Areas for Tremolite-Actinolite Asbestos Fibers (Roy F. Weston, 2002).

3. SAMPLING METHODS

A U.S. EPA START member collected air samples during the excavation and truck loading work phase during the removal action. Although it would have been ideal to collect clearance samples after two or three days of dry weather when winds were greater than 10 miles per hour (mph), this was not always possible due to the project time constraints.

Air samples were collected by drawing air through a 25-millimeter-diameter mixed cellulose ester filter three-piece cassette with a pore size of 0.45 microns (μm) using high-flow air sampling pumps. The filter cassettes were constructed using electrically conductive extension cowls to minimize electrostatic effects on sample collection. Filter cassettes were positioned at a height that would approximate a person's breathing zone (4.5 to 5.5 feet above ground level) and were oriented towards the ground at approximately a 45-degree angle. The high-flow air sampling pumps were set at flow rates between 10 and 16 liters per minute (L/min). Flow rates above 16 L/min were avoided due to the risk of damage to the filter, leakage of air around the filter, or damage to asbestos structures as discussed in the *U.S. EPA Environmental Response Team (ERT) Standard Operating Procedure (SOP) 2015, Asbestos Sampling* (U.S. EPA, 1994) located in Attachment B.

The flow rates of the sampling pumps were measured immediately before and after each sampling interval using a rotameter that had been previously calibrated to a primary calibration unit. The results of this calibration and the corresponding rotameter-specific correction curve and equation (Attachment C) were considered when estimating the actual flow rates for each sample. The average of the pre-and post-sampling final flow rates was used to calculate the final air volume. Sample volumes during the removal action ranged from 1,353 to 6,878 liters per sample.

The parameters for sample collection depended on the following factors: the project-specific AQO of 0.001 S/cc, levels of asbestos in the air, and the level of interfering non-asbestos particulates in the air. Although target volumes ranged from 3,500 to 4,500 liters per sample, actual sample volumes were influenced by weather conditions and the potential for overloading due to excavation activities. Table 1 presents alternative air flow rate conditions based on differing sampling and analysis conditions needed to achieve different sensitivities. The collection conditions in the shaded row correspond to the target conditions for this project. The sampling results are estimated to have a detection limit of approximately 0.0004 (dependent on the ratio of long fibers to total fibers and on the level of interfering non-asbestos particulates).

The details of the sampling methods are provided in the U.S. EPA, ERT SOP 2015 Asbestos Sampling document (U.S. EPA, 1994). Air sampling methodologies were also used in accordance with the procedures set forth within the START Residential Asbestos Remediation Work Plan (Roy F. Weston, 2001) and the Western Mineral Products Site Sampling and Quality Assurance Project Plan (Roy F. Weston, 2001). WESTON START conducted air sampling and provided documentation of the sampling activities.

3.1 SAMPLING IDENTIFICATION SYSTEM

Each air sample was assigned a unique sample identifier. The sample identifier used consisted of the following components:

> Sample Matrix Identifier – A one-digit code to identify the matrix of sample collected, the code "A" corresponds to air samples.
>
> Analysis Method Identifier – A one-digit code to identify the analytical method used for sample analysis, the code "T" corresponds to the transmission electron microscopy (TEM) method.
>
> Sample Date Identifier – A six-digit code to identify the sampling date; the code consists of the month (two-digit format), day (two-digit format), and year (two-digit format).
>
> Work Identifier – A two- or three-digit code to identify the type of work completed when the sample was collected. "EX" identifies the work as excavation.
>
> Work Site Identifier – A numeric code corresponding to the HHID of the work site.
>
> Sampling Location Identifier – A code corresponding to the site-specific location and the alphabetic daily count of the samples.

For example, the sample ID AT-101706-EX322A is comprised of the following components:

A	–	Air sample
T	–	TEM analytical method

101706	–	October 17, 2006, date of collection
EX	–	Excavation work site
IND	–	HHID #322 work site
A	–	Sample location A

3.2 AIR SAMPLE DOCUMENTATION

Air sampling forms were completed for every sampling event. These forms included the following information: date, time, location, sampling personnel, sample identification numbers, pump identification numbers, beginning and ending air flow rates, sampling start and stop times, commutative run times and final volume. The results of primary calibration on the rotometer and the corresponding rotameter-specific correction curve and equation were incorporated in the air sampling forms. An example of an air sampling form and sample location map are provided in Attachment D.

During the 2006 removal action period, all air samples were stored in an upright position within a dedicated sample container until they were shipped to STAT Analysis Corporation (STAT), located in Chicago, Illinois, under chain-of-custody protocol. The chains-of-custody used during this project are provided as Attachment E. STAT is accredited by the United States National Institute of Standards and Technology National Voluntary Laboratory Accreditation Program. STAT's (U.S. NIST NVLAP) certificates of accreditation are provided in Attachment F. The sample analyses complied with the Code of Federal Regulations, Title 40, Chapter I, Subchapter R, Part 763, Subpart E, Appendix A, Section II, as amended through October 30, 1987.

Summaries of climatological data for June to October 2005 and July to September 2006 are included as Attachment G. The summaries were obtained from the Central Region of the National Weather Service (2006) and were collected to identify possible correlations between climate conditions and elevated airborne asbestos concentrations.

Photographic documentation collected throughout the 2006 removal action process by the U.S. START member is provided as Attachment H.

4. ANALYTICAL METHOD REQUIREMENTS

All air samples were analyzed by the TEM method using the Asbestos Hazard Emergency

Response Act (AHERA) protocol. The TEM sampling method identifies the specific type of asbestos fibers in a sample including: actinolite; amosite; anthophyllite; chrysotile; crocidolite; and tremolite. The results of air sampling were used to monitor the amounts of asbestos fibers detected in air at the perimeter of excavation. STAT was contracted to analyze all of the collected air samples. The analysis complies with the Code of Federal Regulations (CFR) Title 40, Chapter I, Subchapter R, Part 763, Subpart E, Appendix A, Section II, as amended through October 30, 1987. A copy of STAT's TEM protocols is not provided in this report, however a copy of their TEM and PLM U.S. NIST NVLAP certification is provided in Attachment F.

5. ANALYTICAL REPORTS

All air samples were submitted to STAT during the removal action. A U.S. EPA START member collected and compiled all analytical reports in both hard copy and electronic database formats. A summary of the soil analytical reports related to the two target properties is provided as Attachment I.

6. SUMMARY

The removal action at the HHID #817 property included the excavation of asbestos contaminated soil from an approximate area of 100-square-feet and approximate depth of 6 inches. Two AT air samples were collected during excavation activities and analyzed using the TEM analytical method. The results of this analysis were used to evaluate the amount and type of asbestos fibers detected in air near the perimeter of excavation. The TEM perimeter air results indicate that during excavation activities at the HHID #817 property asbestos fibers were detected at less than 0.001 structures per cubic centimeter (S/cc).

The excavation of asbestos contaminated soil at the HHID #322 property consisted of an approximate area of 2.6 acres and an approximate depth of 2 feet. 490 air samples were collected during excavation activities and analyzed using the TEM analytical method. The results of this analysis were used to evaluate the amount and type of asbestos fibers detected in air near the perimeter of excavation. 48 air samples reported concentrations greater than 0.001 S/cc with a maximum result of 0.008 S/cc. Asbestos concentrations in all remaining 442 air samples reported concentrations equal to or below 0.001.

7. CONCLUSION

The TEM analytical air results of the perimeter air monitoring samples collected at the HHID #817 property indicate that asbestos fibers were detected below the project-specific air quality objective (AQO) of 0.001 S/cc asbestos for the Phase II WMP removal action sites. Therefore; dust control measures conducted during excavation activities were effective. The climatological data indicated that influences of outside factors such as ambient climate conditions proved to be minimal.

Of the 48 air samples collected at the HHID #322 property reporting results above the AQO, 26 samples, collected between 13 June 2005 and 16 June 2005, were analyzed with an increased analytical sensitivity and reporting quantities were above the AQO. An example includes the maximum asbestos concentration which was reported on 14 June 2005 as 0.008 S/cc. The 14 June 2005 asbestos concentrations were associated with above AQO reporting limits of 0.004. Following that period, the analytical sensitivity was decreased to the AQO. Throughout the removal action, when concentrations above 0.001 S/cc were measured from the laboratory samples, dust control techniques were re-visited, and airborne levels of dust decreased. Outside factors, such as ambient climate conditions, proved to have an effect on the air analytical results; however, the influence was minimal. For example, the highest concentrations of asbestos measured during removal activities were measured on 4 August 2006, reported as 0.004 S/cc for tremolite and chrysotile asbestos. The 4 August 2006 results were associated with above-average wind speeds of 11.9 miles per hour (mph) compared to an average wind speed during that August 2006 of 7.6 mph. Higher-than-average wind speeds may have aided in the suspension of asbestos in the ambient air.

Following excavation activities, the excavated area was backfilled and restored to pre-existing conditions with two feet of clean fill (as determined through laboratory analysis) over the entire excavation area. Furthermore, a geothermal liner was installed to serve as an indicator of where the excavation stopped. All soil removed from the property was secured in a truck lined with 3 millimeter plastic liner, duct tape, and transported to the Veolia Environmental Services Landfill Facility, formally known as Onyx Landfill in Buffalo, Minnesota.

To date, a comprehensive total of 266 properties have been identified as having tremolite asbestos contamination. Removal action has been completed at 253 properties, including the WMP Industrial Facility (HHID #1653). The remaining thirteen properties have either denied access or not responded to requests for access.

8. REFERENCES

National Weather Service Forecast Office, Twin Cities, Minneapolis. Available at: http://www.crh.noaa.gov/mpx/climate.html, updated 29 December 2006.

Roy F. Weston (currently Weston Solutions, Inc). Residential Asbestos Remediation Work Plan for Western Minerals Products Site Minneapolis, Minnesota. 2001.

Roy F. Weston (currently Weston Solutions, Inc). Western Mineral Products Site Sampling and Quality Assurance Project Plan. 2001.

Roy F. Weston (currently Weston Solutions, Inc), Environmental Sampling for Asbestos - Work Zone Air Sampling in Residential Areas for Tremolite-Actinolite Asbestos Fibers. January 18, 2002.

U.S. EPA, Environmental Response Team, Asbestos Sampling; SOP #2015 Revision 0.0. November 17, 1994.

U.S. EPA, Guidelines for Conducting the AHERA TEM Clearance Test to Determine Completion of an Asbestos Abatement Project. Document 560/5-89 001. May 1989.

TABLE 1

Alternative Air Sampling and Analysis Methods

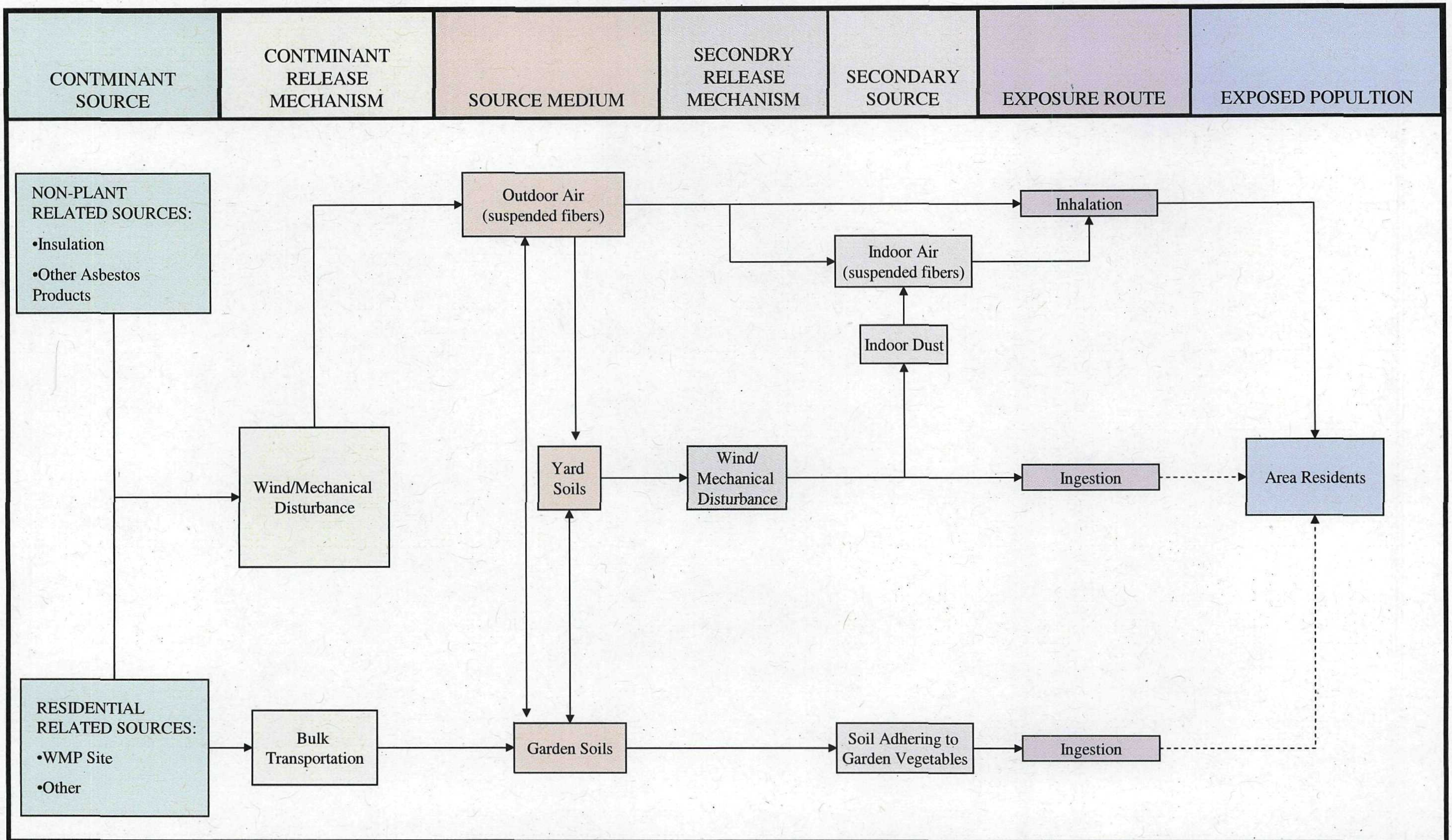
Table 1
Alternative Air Sampling and Analysis Methods
Western Mineral Products Site
Minneapolis, Minnesota

Target Risk (f/mL)a	Assumed Percent Fiber >10 µm in Length	Concentration of Concern (f/mL)a	Suggested Sampling and Analysis Parameters[b]			
			Grid Openings	V (L)	Flow (L/min)	Time (hrs)
1.00E-02	1%	3.50E-02	4	900	1	15
	10%	4.50E-03	8	3800	3	21
1.00E-03	1%	3.50E-03	10	4000	10	7
	10%	4.50E-04	40	8000	10	13
1.00E-04	1%	3.50E-03	40	8500	10	14
	10%	4.50E-04	60	50000	16	52

NOTES:
f/mL = fibers per milliliter
[a]Based on average unit risk to smokers. Quantitative toxicity values for asbestos-induced cancer are uncertain, so the concentration values listed should not be viewed as discrete values between "acceptable" and "unacceptable".
[b]Grid openings and air volume required to quantify asbestos at approximately 33% the target risk level.
um = micrometer
L = Liter
L/min = Liters per minute
hrs = hours
= Indicates target samling condition.

ATTACHMENT A

Conceptual Site Exposure Model



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U.S. EPA Region V
Superfund Technical Assessment and
Response Team
Contract No. 68-00-W-119

LEGEND

⟶ Pathway is potentially complete and considered significant; qualitative evaluation

- - - → Pathway is potentially complete, but not considered significant; qualitative evaluation

ATTACHMENT: A **TITLE:** Conceptual Site Exposure Model

SITE: Western Mineral Products

CITY: Minneapolis **STATE:** MN

TDD: S05-0609-038 **DCN:** 038-2A-AAGV

DATE: 23 January 2007

ATTACHMENT B

U.S. EPA SOP 2015 Asbestos Sampling

ASBESTOS SAMPLING

SOP#: 2015
DATE: 11/17/94
REV. #: 0.0

1.0 SCOPE AND APPLICATION

Asbestos has been used in many commercial products including building materials such as flooring tiles and sheet goods, paints and coatings, insulation, and roofing asphalts. These products and others may be found at hazardous waste sites hanging on overhead pipes, contained in drums, abandoned in piles, or as part of a structure. Asbestos tailing piles from mining operations can also be a source of ambient asbestos fibers. Asbestos is a known carcinogen and requires air sampling to assess airborne exposure to human health. This Standard Operating Procedure (SOP) provides procedures for asbestos air sampling by drawing a known volume of air through a mixed cellulose ester (MCE) filter. The filter is then sent to a laboratory for analysis. The U.S. Environmental Protection Agency/Environmental Response Team (U.S. EPA/ERT) uses one of four analytical methods for determining asbestos in air. These include: U.S. EPA's Environmental Asbestos Assessment Manual, Superfund Method for the Determination of Asbestos in Ambient Air for Transmission Electron Microscopy (TEM)[1]; U.S. EPA's Modified Yamate Method for TEM[2]; National Institute for Occupational Safety and Health (NIOSH) Method 7402 (direct method only) for TEM; and NIOSH Method 7400 for Phase Contrast Microscopy (PCM)[3]. Each method has specific sampling and analytical requirements (i.e., sample volume and flow rate) for determining asbestos in air.

The U.S. EPA/ERT typically follows procedures outlined in the TEM methods for determining mineralogical types of asbestos in air and for distinguishing asbestos from non-asbestos minerals. The Phase Contrast Microscopy (PCM) method is used by U.S. EPA/ERT as a screening tool since it is less costly than TEM. PCM cannot distinguish asbestos from non-asbestos fibers, therefore the TEM method may be necessary to confirm analytical results. For example, if an action level for the presence of fibers has been set and PCM analysis indicates that the action level has been exceeded, then TEM analysis can be used to quantify and identify asbestos structures through examination of their morphology crystal structures (through electron diffraction), and elemental composition (through energy dispersive X-ray analysis). In this instance samples should be collected for both analyses in side by side sampling trains (some laboratories are able to perform PCM and TEM analysis from the same filter). The Superfund method is designed specifically to provide results suitable for supporting risk assessments at Superfund sites, it is applicable to a wide range of ambient air situations at hazardous waste sites. U.S. EPA's Modified Yamate Method for TEM is also used for ambient air sampling due to high volume requirements. The PCM and TEM NIOSH analytical methods require lower sample volumes and are typically used indoors; however, ERT will increase the volume requirement for outdoor application.

Other Regulations pertaining to asbestos have been promulgated by U.S. EPA and OSHA. U.S. EPA's National Emission Standards for Hazardous Air Pollutants (NESHAP) regulates asbestos-containing waste materials. NESHAP establishes management practices and standards for the handling of asbestos and emissions from waste disposal operations (40 CFR Part 61, Subparts A and M). U.S. EPA's 40 CFR 763 (July 1, 1987)[4] and its addendum 40 CFR 763 (October 30, 1987)[4] provide comprehensive rules for the asbestos abatement industry. State and local regulations on these issues vary and may be more stringent than federal requirements. The OSHA regulations in 29 CFR 1910.1001 and 29 CFR 1926.58 specify work practices and safety equipment such as respiratory protection and protective clothing when handling asbestos. The OSHA standard for an 8-hour, time-weighted average (TWA) is 0.2 fibers/cubic centimeters of air. This standard pertains to fibers with a length-to-width ratio of 3 to 1 with a fiber length >5 µm[5,6]. An action level of 0.1 fiber/cc (one-half the OSHA standard) is the level U.S. EPA has established in which employers must initiate such activities as air monitoring, employee training, and medical surveillance[5,6].

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent upon site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

Mention of trade names or commercial products does not constitute U.S. EPA endorsement or recommendation for use.

2.0 METHOD SUMMARY

Prior to sampling, the site should be characterized by identifying on-site as well as off-site sources of airborne asbestos. The array of sampling locations and the schedule for sample collection, is critical to the success of an investigation. Generally, sampling strategies to characterize a single point source are fairly straightforward, while multiple point sources and area sources increase the complexity of the sampling strategy. It is not within the scope of this SOP to provide a generic asbestos air sampling plan. Experience, objectives, and site characteristics will dictate the sampling strategy.

During a site investigation, sampling stations should be arranged to distinguish spatial trends in airborne asbestos concentrations. Sampling schedules should be fashioned to establish temporal trends. The sampling strategy typically requires that the concentration of asbestos at the source (worst case) or area of concern (downwind), crosswind, as well as background (upwind) contributions be quantified. See Table 1 (Appendix A) for U.S. EPA/ERT recommended sampling set up for ambient air. Indoor asbestos sampling requires a different type of strategy which is identified in Table 2 (Appendix A). It is important to establish background levels of contaminants in order to develop a reference point from which to evaluate the source data. Field blanks and lot blanks can be utilized to determine other sources.

Much information can be derived from each analytical method previously mentioned. Each analytical method has specific sampling requirements and produce results which may or may not be applicable to a specific sampling effort. The site sampling objectives should be carefully identified so as to select the most appropriate analytical method. Additionally, some preparation (i.e., lot blanks results) prior to site sampling may be required, these requirements are specified in the analytical methods.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

3.1 Sample Preservation

No preservation is required for asbestos samples.

3.2 Sample Handling, Container and Storage Procedures

1. Place a sample label on the cassette indicating a unique sampling number. Do not put sampling cassettes in shirt or coat pockets as the filter can pick up fibers. The original cassette box is used to hold the samples.

2. Wrap the cassette individually in a plastic sample bag. Each bag should be marked indicating sample identification number, total volume, and date.

3. The wrapped sampling cassettes should be placed upright in a rigid container so that the cassette cap is on top and cassette base is on bottom. Use enough packing material to prevent jostling or damage. Do not use vermiculite as packing material for samples. If possible, hand carry to lab.

4. Provide appropriate documentation with samples (i.e., chain of custody and requested analytical methodology).

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

Flow rates exceeding 16 liters/minute (L/min) which could result in filter destruction due to (a) failure of its physical support under force from the increased pressure drop; (b) leakage of air around the filter mount so that the filter is bypassed, or (c) damage to the asbestos structures due to increased impact velocities.

4.1 U.S. EPA's Superfund Method

4.1.1 Direct-transfer TEM Specimen Preparation Methods

Direct-Transfer TEM specimen preparation methods have the following significant interferences:

- C The achievable detection limit is restricted by the particulate density on the filter, which in turn is controlled by the sampled air volume and the total suspended particulate concentration in the atmosphere being sampled.

- C The precision of the result is dependent on the uniformity of the deposit of asbestos structures on the sample collection filter.

- C Air samples must be collected so that they have particulate and fiber loadings within narrow ranges. If too high a particulate loading occurs on the filter, it is not possible to prepare satisfactory TEM specimens by a direct-transfer method. If too high a fiber loading occurs on the filter, even if satisfactory TEM specimens can be prepared, accurate fiber counting will not be possible.

4.1.2 Indirect TEM Specimen Preparation Methods

Indirect TEM specimen preparation methods have the following interferences:

- C The size distribution of asbestos structures is modified.

- C There is increased opportunity for fiber loss or introduction of extraneous contamination.

- C When sample collection filters are ashed, any fiber contamination in the filter medium is concentrated on the TEM specimen grid.

It can be argued that direct methods yield an under-estimate of the asbestos structure concentration because many of the asbestos fibers present are concealed by other particulate material with which they are associated. Conversely, indirect methods can be considered to yield an over-estimate because some types of complex asbestos structures disintegrate during the preparation, resulting in an increase in the numbers of structures counted.

4.2 U.S. EPA's Modified Yamate Method for TEM

High concentrations of background dust interfere with fiber identification.

4.3 NIOSH Method for TEM

Other amphibole particles that have aspect ratios greater than 3:1 and elemental compositions similar to the asbestos minerals may interfere in the TEM analysis. Some non-amphibole minerals may give electron diffraction patterns similar to amphiboles. High concentrations of background dust interfere with fiber identification.

4.4 NIOSH Method for PCM

PCM cannot distinguish asbestos from non-asbestos fibers; therefore, all particles meeting the counting criteria are counted as total asbestos fibers. Fiber less than 0.25 um in length will not be detected by this method. High levels of non-fibrous dust particles may obscure fibers in the field of view and increase the detection limit.

5.0 EQUIPMENT/MATERIALS

5.1 Sampling Pump

The constant flow or critical orifice controlled sampling pump should be capable of a flow-rate and pumping time sufficient to achieve the desired volume of air sampled.

The lower flow personal sampling pumps generally provide a flow rate of 20 cubic centimeters/minute (cc/min) to 4 L/min. These pumps are usually battery powered. High flow pumps are utilized when flow rates between 2 L/min to 20 L/min are required. High flow pumps are used for short sampling periods so as to obtain the desired sample volume. High flow pumps usually run on AC power and can be plugged into a nearby outlet. If an outlet is not available then a generator should be obtained. The generator should be positioned downwind from the sampling pump. Additional voltage may be required if more than one pump is plugged into the same generator. Several electrical extension cords may be required if sampling locations are remote.

The recommended volume for the Superfund method (Phase I) requires approximately 20 hours to collect. Such pumps typically draw 6 amps at full power so that 2 lead/acid batteries should provide sufficient power to collect a full sample. The use of line voltage, where available, eliminates the difficulties associated with transporting stored electrical energy.

A stand should be used to hold the filter cassette at the desired height for sampling and the filter cassette shall be isolated from the vibrations of the pump.

5.2 Filter Cassette

The cassettes are purchased with the required filters in position, or can be assembled in a laminar flow hood or clean area. When the filters are in position, a shrink cellulose band or adhesive tape should be applied to cassette joints to prevent air leakage.

5.2.1 TEM Cassette Requirements

Commercially available field monitors, comprising 25 mm diameter three-piece cassettes, with conductive extension cowls shall be used for sample collection. The cassette must be new and not previously used. The cassette shall be loaded with an MCE filter of pore size 0.45 μm, and supplied from a lot number which has been qualified as low background for asbestos determination. The cowls should be constructed of electrically conducting material to minimize electrostatic effects. The filter shall be backed by a 5 μm pore size MCE filter (Figure 1, Appendix B).

5.2.2 PCM Cassette Requirements

NIOSH Method 7400, PCM involves using a 0.8 to 1.2 μm mixed cellulose ester membrane, 25 mm diameter, 50 mm conductive cowl on cassette (Figure 2, Appendix B). Some labs are able to perform PCM and TEM analysis on the same filter; however, this should be discussed with the laboratory prior to sampling.

5.3 Other Equipment

- Inert tubing with glass cyclone and hose barb
- Whirlbags (plastic bags) for cassettes
- Tools - small screw drivers
- Container - to keep samples upright
- Generator or electrical outlet (may not be required)
- Extension cords (may not be required)
- Multiple plug outlet
- Sample labels
- Air data sheets
- Chain of Custody records

6.0 REAGENTS

Reagents are not required for the preservation of asbestos samples.

7.0 PROCEDURES

7.1 Air Volumes and Flow Rates

Sampling volumes are determined on the basis of how many fibers need to be collected for reliable measurements. Therefore, one must estimate how many airborne fibers may be in the sampling location.

Since the concentration of airborne aerosol contaminants will have some effect on the sample, the following is a suggested criteria to assist in selecting a flow rate based on real-time aerosol monitor (RAM) readings in milligrams/cubic meter (mg/m^3).

	Concentration	Flow Rate
Low RAM readings:	<6.0 mg/m^3	11-15. L/min
Medium RAM readings:	>6.0 mg/m$_3$	7.5 L/min
High RAM readings:	>10. mg/m^3	2.5 L/min

In practice, pumps that are available for environmental sampling at remote locations operate under a maximum load of approximately 12 L/min.

7.1.1 U.S. EPA's Superfund Method

The Superfund Method incorporates an indirect preparation procedure to provide flexibility in the amount of deposit that be can be tolerated on the sample filter and to allow for the selective concentration of asbestos prior to analysis. To minimize contributions to background contamination from asbestos present in the plastic matrices of membrane filters while allowing for sufficient quantities of asbestos to be collected, this method also requires the collection of a larger volume of air per unit area of filter than has traditionally been collected for asbestos analysis. Due to the need to collect large volumes of air, higher sampling flow rates are recommended in this method than have generally been employed for asbestos sampling in the past. As an alternative, samples may be collected over longer time intervals. However, this restricts the flexibility required to allow samples to be collected while uniform meteorological conditions prevail.

The sampling rate and the period of sampling should be selected to yield as high a sampled volume as possible, which will minimize the influence of filter contamination. Wherever possible, a volume of 15 cubic meters (15,000 L) shall be sampled for those samples intended for analysis only by the indirect TEM preparation method (Phase 1 samples). For those samples to be prepared by both the indirect and the direct specimen preparation methods (Phase 2 samples), the volumes must be adjusted so as to provide a suitably-loaded filter for the direct TEM preparation method. One option is to collect filters at several loadings to bracket the estimated optimum loading for a particular site. Such filters can be screened in the laboratory so that only those filters closest to optimal loading are analyzed. It has been found that the volume cannot normally exceed 5 cubic meters (5000 L) in an urban or agricultural area, and 10 cubic meters (10,000 L) in a rural area for samples collected on a 25 mm filter and prepared by a direct-transfer technique.

An upper limit to the range of acceptable flow rates for this method is 15 L/min. At many locations, wind patterns exhibit strong diurnal variations. Therefore, intermittent sampling (sampling over a fixed time interval repeated over several days) may be necessary to accumulate 20 hours of sampling time over constant wind conditions. Other sampling objectives also may necessitate intermittent sampling. The objective is to design a sampling schedule so that samples are collected under uniform conditions throughout the sampling interval. This method provides for such options. Air volumes collected on Phase I samples are maximized (<16 L/min). Air volumes collected on Phase 2 samples are limited to provide optimum loading for filters to be prepared by a direct-transfer procedure.

7.1.2 U.S. EPA's Modified Yamate Method for TEM

U.S. EPA's TEM method requires a minimum volume of 560 L and a maximum volume of 3,800 L in order to obtain an analytical sensitivity of 0.005 structures/cc. The optimal volume for TEM is 1200 L to 1800 L. These volumes are determined using a 200 mesh EM grid opening with a 25-mm filter cassette. Changes in volume would be necessary if a 37-mm filter cassette is used since the effective area of a 25 mm (385 sq mm) and 37 mm (855 sq m) differ.

7.1.3 NIOSH Method for TEM and PCM

The minimum recommended volume for TEM and PCM is 400 L at 0.1 fiber/cc. Sampling time is adjusted to obtain optimum fiber loading on the filter. A sampling rate of 1 to 4 L/min for eight hours (700 to 2800 L) is appropriate in non-dusty atmospheres containing 0.1 fiber/cc. Dusty atmospheres i.e., areas with high levels of asbestos, require smaller sample volumes (<400 L) to obtain countable samples.

In such cases, take short, consecutive samples and average the results over the total collection time. For documenting episodic exposures, use high flow rates (7 to 16 L/min) over shorter sampling times. In relatively clean atmospheres where targeted fiber concentrations are much less than 0.1 fiber/cc, use larger sample volumes (3,000 to 10,000 L) to achieve quantifiable loadings. Take care, however, not to overload the filter with background dust. If > 50% of the filter surface is covered with particles, the filter may be too overloaded to count and will bias the measured fiber concentration. Do not exceed 0.5 mg total dust loading on the filter.

7.2 Calibration Procedures

In order to determine if a sampling pump is measuring the flow rate or volume of air correctly, it is necessary to calibrate the instrument. Sampling pumps should be calibrated immediately before and after each use. Preliminary calibration should be conducted using a primary calibrator such as a soap bubble type calibrator, (e.g., a Buck Calibrator, Gilibrator, or equivalent primary calibrator) with a representative filter cassette installed between the pump and the calibrator. The representative sampling cassette can be reused for calibrating other pumps that will be used for asbestos sampling. The same cassette lot used for sampling should also be used for the calibration. A sticker should be affixed to the outside of the extension cowl marked "Calibration Cassette."

A rotameter can be used provided it has been recently precalibrated with a primary calibrator. Three separate constant flow calibration readings should be obtained both before sampling and after sampling. Should the flow rate change by more than 5% during the sampling period, the average of the pre- and post-calibration rates will be used to calculate the total sample volume. The sampling pump used shall provide a non-fluctuating air-flow through the filter, and shall maintain the initial volume flow-rate to within ± 10% throughout the sampling period. The mean value of these flow-rate measurements shall be used to calculate the total air volume sampled. A constant flow or critical orifice controlled pump meets these requirements. If at any time the measurement indicates that the flow-rate has decreased by more than 30%, the sampling shall be terminated. Flexible tubing is used to connect the filter cassette to the sampling pump.Sampling pumps can be calibrated prior to coming on-site so that time is saved when performing on-site calibration.

7.2.1 Calibrating a Personal Sampling Pump with an Electronic Calibrator

1. See Manufacturer's manual for operational instructions.

2. Set up the calibration train as shown in (Figure 3, Appendix B) using a sampling pump, electronic calibrator, and a representative filter cassette. The same lot sampling cassette used for sampling should also be used for calibrating.

3. To set up the calibration train, attach one end of the PVC tubing (approx. 2 foot) to the cassette base; attach the other end of the tubing to the inlet plug on the pump. Another piece of tubing is attached from the cassette cap to the electronic calibrator.

4. Turn the electronic calibrator and sampling pump on. Create a bubble at the bottom of the flow chamber by pressing the bubble initiate button. The bubble should rise to the top of the flow chamber. After the bubble runs its course, the flow rate is shown on the LED display.

5. Turn the flow adjust screw or knob on the pump until the desired flow rate is attained.

6. Perform the calibration three times until the desired flow rate of ± 5% is attained.

7.2.2 Calibrating a Rotameter with an Electronic Calibrator

1. See manufacturer's manual for operational instructions.

2. Set up the calibration train as shown in (Figure 4, Appendix B) using a sampling pump, rotameter, and electronic calibrator.

3. Assemble the base of the flow meter with the screw provided and tighten in place. The flow meter should be mounted within 6° vertical.

4. Turn the electronic calibrator and sampling pump on.

5. Create a bubble at the bottom of the flow chamber by pressing the bubble initiate button. The bubble should rise to the top of the flow chamber. After the bubble runs its course, the flow rate is shown on the LED display.

6. Turn the flow adjust screw or knob on the pump until the desired flow rate is attained.

7. Record the electronic calibrator flow rate reading and the corresponding rotameter reading. Indicate these values on the rotameter (sticker). The rotameter should be able to work within the desired flow range. Readings can also be calibrated for 10 cm^3 increments for Low Flow rotameters, 500 cm^3 increments for medium flow rotameters and 1 liter increments for high flow rotameters.

8. Perform the calibration three times until the desired flow rate of ± 5% is attained. Once on site, a secondary calibrator, i.e., rotameter may be used to calibrate sampling pumps.

7.2.3 Calibrating a Personal Sampling Pump with a Rotameter

1. See manufacturer's manual for Rotameter's Operational Instructions.

2. Set up the calibration train as shown in (Figure 5, Appendix B) using a rotameter, sampling pump, and a representative sampling cassette.

3. To set up the calibration train, attach one end of the PVC tubing (approx. 2 ft) to the cassette base; attach the other end of the tubing to the inlet plug on the pump. Another piece of tubing is attached from the cassette cap to the rotameter.

4. Assemble the base of the flow meter with the screw provided and tighten in place. The flow meter should be mounted within 6° vertical.

5. Turn the sampling pump on.

6. Turn the flow adjust screw (or knob) on the personal sampling pump until the float ball on the rotameter is lined up with the precalibrated flow rate value. A sticker on the rotameter should indicate this value.

7. A verification of calibration is generally performed on-site in the clean zone immediately prior to the sampling.

7.3. Meteorology

It is recommended that a meteorological station be established. If possible, sample after two to three days of dry weather and when the wind conditions are at 10 mph or greater. Record wind speed, wind direction, temperature, and pressure in a field logbook. Wind direction is particularly important when monitoring for asbestos downwind from a fixed source.

7.4 Ambient Sampling Procedures

7.4.1 Pre-site Sampling Preparation

1. Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies needed.

2. Obtain necessary sampling equipment and ensure it is in working order and fully charged (if necessary).

3. Perform a general site survey prior to site entry in accordance with the site specific Health and Safety plan.

4. Once on-site the calibration is performed in the clean zone. The calibration procedures are listed in Section 7.2.

5. After calibrating the sampling pump, mobilize to the sampling location.

7.4.2 Site Sampling

1. To set up the sampling train, attach the air intake hose to the cassette base. Remove the cassette cap (Figure 6 and 7, Appendix B). The cassette should be positioned downward, perpendicular to the wind

2. If AC or DC electricity is required then turn it on. If used, the generator should be placed 10 ft. downwind from the sampling pump.

3. Record the following in a field logbook: date, time, location, sample identification number, pump number, flow rate, and cumulative time.

4. Turn the pump on. Should intermittent sampling be required, sampling filters must be covered between active periods of sampling. To cover the sample filter: turn the cassette to face upward, place the cassette cap on the cassette, remove the inlet plug from the cassette cap, attach a rotameter to the inlet opening of the cassette cap to measure the flow rate, turn off the sampling pump, place the inlet plug into the inlet opening on the cassette cap. To resume sampling: remove the inlet plug, turn on the sampling pump, attach a rotameter to measure the flow rate, remove the cassette cap, replace the inlet plug in the cassette cap and invert the cassette, face downward and perpendicular to the wind.

5. Check the pump at sampling midpoint if sampling is longer than 4 hours. The generators may need to be regased depending on tank size. If a filter darkens in appearance or if loose dust is seen in the filter, a second sample should be started.

6. At the end of the sampling period, orient the cassette up, turn the pump off.

7. Check the flow rate as shown in Section 7.2.3. When sampling open-faced, the sampling cap should be replaced before post calibrating. Use the same cassette used for sampling for post calibration (increase dust/fiber loading may have altered the flow rate.

8. Record the post flow rate.

9. Record the cumulative time or run.

10. Remove the tubing from the sampling cassette. Still holding the cassette upright, replace the inlet plug on the cassette cap and the outlet plug on the cassette base.

7.4.3. Post Site Sampling

1. Follow handling procedures in Section 3.2, steps 1-4.

2. Obtain an electronic or hard copy of meteorological data which occurred during the sampling event. Record weather: wind speed, ambient temperature, wind direction, and precipitation. Obtaining weather data several days prior to the sampling event can also be useful.

7.5 Indoor Sampling Procedures

PCM analysis is used for indoor air samples. When analysis shows total fiber count above the OSHA action level 0.1 f/cc then TEM (U.S. EPA's Modified Yamate Method) is used to identify asbestos from non-asbestos fibers.

Sampling pumps should be placed four to five feet above ground level away from obstructions that may influence air flow. The pump can be placed on a table or counter. Refer to Table 2 (Appendix A) for a summary of indoor sampling locations and rationale for selection.

Indoor sampling utilizes high flow rates to increased sample volumes (2000 L for PCM and 2800 to 4200 L for TEM) in order to obtain lower detection limits below the standard, (i.e., 0.01 f/cc or lower [PCM] and 0.005 structures/cc or lower [TEM]).

7.5.1 Aggressive Sampling Procedures

Sampling equipment at fixed locations may fail to detect the presence of asbestos fibers. Due to limited air movement, many fibers may settle out of the air onto the floor and other surfaces and may not be captured on the filter. In the past, an 8-hour sampling period was recommended to cover various air circulation conditions. A quicker and more effective way to capture asbestos fibers is to circulate the air artificially so that the fibers remain airborne during sampling. The results from this sampling option typifies worst case condition. This is referred to as aggressive air sampling for asbestos. Refer to Table 2 for sample station locations.

1. Before starting the sampling pumps, direct forced air (such as a 1-horsepower leaf blower or large fan) against walls, ceilings, floors, ledges, and other surfaces in the room to initially dislodge fibers from surfaces. This should take at least 5 minutes per 1000 sq. ft. of floor.

2. Place a 20-inch fan in the center of the room. (Use one fan per 10,000 cubic feet of room space.) Place the fan on slow speed and point it toward the ceiling.

3. Follow procedures in Section 7.4.1 and 7.4.2 (Turn off the pump and then the fan(s) when sampling is complete.).

4. Follow handling procedures in Section 3.2, steps 1-4.

8.0 CALCULATIONS

The sample volume is calculated from the average flow rate of the pump multiplied by the number of minutes the pump was running (volume = flow rate X time in minutes). The sample volume should be submitted to the laboratory and identified on the chain of custody for each sample (zero for lot, field and trip blanks).

The concentration result is calculated using the sample volume and the numbers of asbestos structures reported after the application of the cluster and matrix counting criteria.

9.0 QUALITY ASSURANCE/ QUALITY CONTROL

Follow all QA/QC requirements from the laboratories as well as the analytical methods.

9.1 TEM Requirements

1. Examine lot blanks to determine the background asbestos structure concentration.

2. Examine field blanks to determine whether there is contamination by extraneous asbestos structures during specimen preparation.

3. Examine of laboratory blanks to determine if contamination is being introduced during critical phases of the laboratory program.

4. To determine if the laboratory can satisfactorily analyze samples of known asbestos structure concentrations, reference filters shall be examined. Reference filters should be maintained as part of the laboratory's Quality Assurance program.

5. To minimize subjective effects, some specimens should be recounted by a different microscopist.

6. Asbestos laboratories shall be accredited by the National Voluntary Laboratory Accreditation Program.

7. At this time, performance evaluation samples for asbestos in air are not available for Removal Program Activities.

9.2 PCM Requirements

1. Examine reference slides of known concentration to determine the analyst's ability to satisfactorily count fibers. Reference slides should be maintained as part of the laboratory's quality assurance program.

2. Examine field blanks to determine if there is contamination by extraneous structures during sample handling.

3. Some samples should be relabeled then submitted for counting by the same analyst to determine possible bias by the analyst.

4. Participation in a proficiency testing program such as the AIHA-NIOSH proficiency analytical testing (PAT) program.

10.0 DATA VALIDATION

Results of quality control samples will be evaluated for contamination. This information will be utilized to qualify the environmental sample results accordingly with the project's data quality objectives.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OSHA, and corporate health and safety procedures. More specifically, when entering an unknown situation involving asbestos, a powered air purifying respirator (PAPR) (full face-piece) is necessary in conjunction with HEPA filter cartridges. See applicable regulations for action level, PEL, TLV, etc. If previous sampling indicates asbestos concentrations are below personal health and safety levels, then Level D personal protection is adequate.

12.0 REFERENCES

(1) Environmental Asbestos Assessment Manual, Superfund Method for the Determination of Asbestos in Ambient Air, Part 1: Method, EPA/540/2-90/005a, May 1990, and Part 2: Technical Background Document, EPA/540/2-90/005b, May 1990.

(2) Methodology for the Measurement of Airborne Asbestos by Electron Microscopy, EPA's Report No. 68-02-3266, 1984, G. Yamate, S.C. Agarwal, and R. D. Gibbons.

(3) National Institute for Occupational Safety and Health. NIOSH Manual of Analytical Method. Third Edition. 1987.

(4) U.S. Environmental Protection Agency. Code of Federal Regulations 40 CFR 763. July 1, 1987. Code of Federal Regulations 40 CFR 763 Addendum. October 30, 1987.

(5) U.S. Environmental Protection Agency. Asbestos-Containing Materials in Schools; Final Rule and Notice. 52 FR 41826.

(6) Occupational Safety and Health Administration. Code of Federal Regulations 29 CFR 1910.1001. Washington, D.C. 1987.

APPENDIX A

Tables

TABLE 1. SAMPLE STATIONS FOR OUTDOOR SAMPLING		
Sample Station Location	Sample Numbers	Rationale
Upwind/Background[1]	Collect a minimum of two simultaneous upwind/background samples 30° apart from the prevailing windlines.	Establishes background fiber levels.
Downwind	Deploy a minimum of 3 sampling stations in a 180 degree arc downwind from the source.	Indicates if asbestos is leaving the site.
Site Representative and/or Worst Case	Obtain one site representative sample which shows average condition on-site or obtain worst case sample (optional).	Verify and continually confirm and document selection of proper levels of worker protection.

[1] More than one background station may be required if the asbestos originates from different sources.

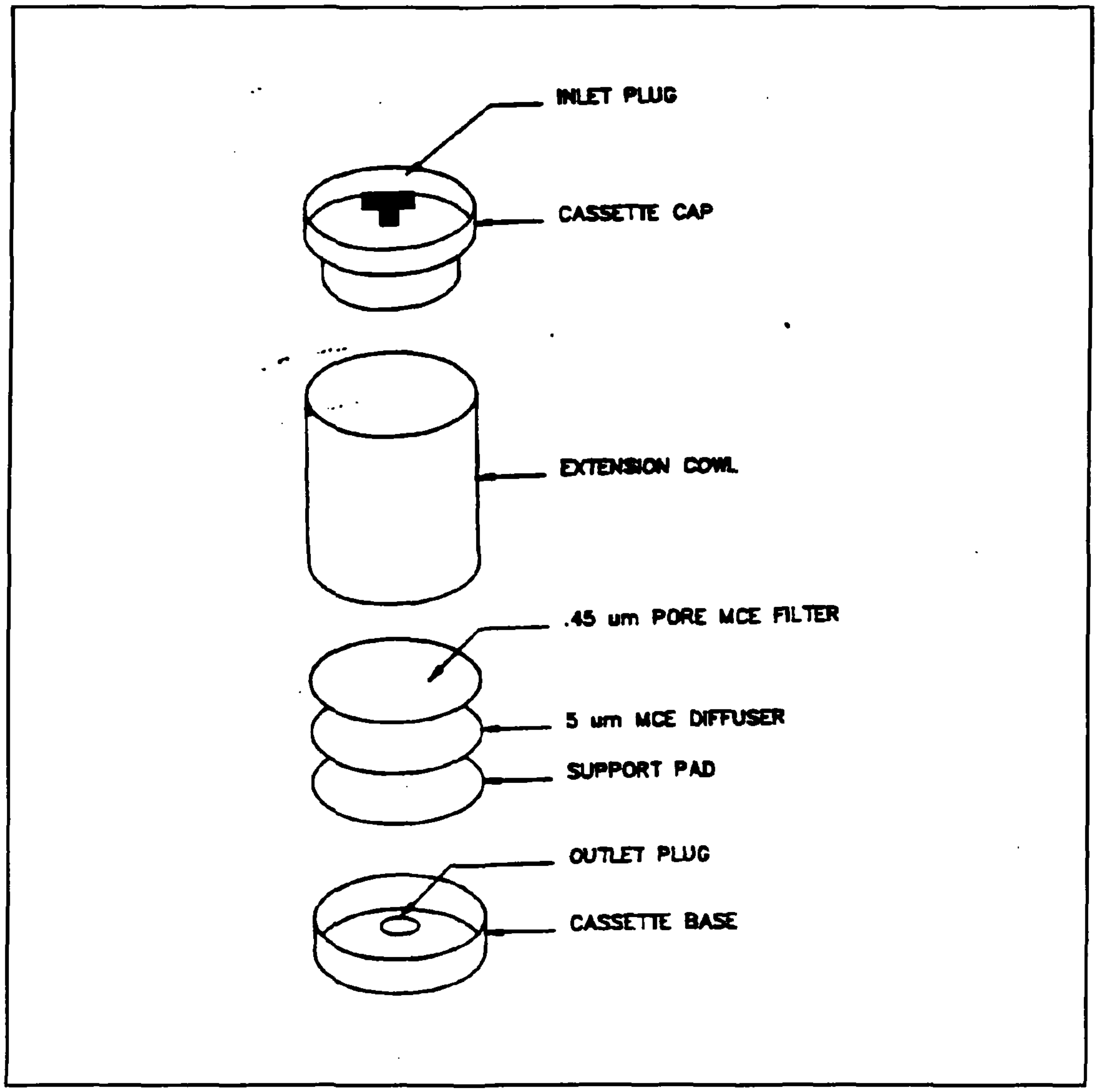
Tables

TABLE 2 SAMPLE STATIONS FOR INDOOR SAMPLING		
Sample Station Location	Sample Numbers	Rationale
Indoor Sampling	If a work site is a single room, disperse 5 samplers throughout the room. If the work site contains up to 5 rooms, place at least one sampler in each room. If the work site contains more than 5 rooms, select a representative sample of the rooms.	Establishes representative samples from a homogeneous area.
Upwind/Background	If outside sources are suspected, deploy a minimum of two simultaneous upwind/background samples 30° apart from the prevailing windlines.	Establish whether indoor asbestos concentrations are coming from an outside source.
Worst Case	Obtain one worst case sample, i.e., aggressive sampling (optional).	Verify and continually confirm and document selection of proper levels of worker protection.

APPENDIX B

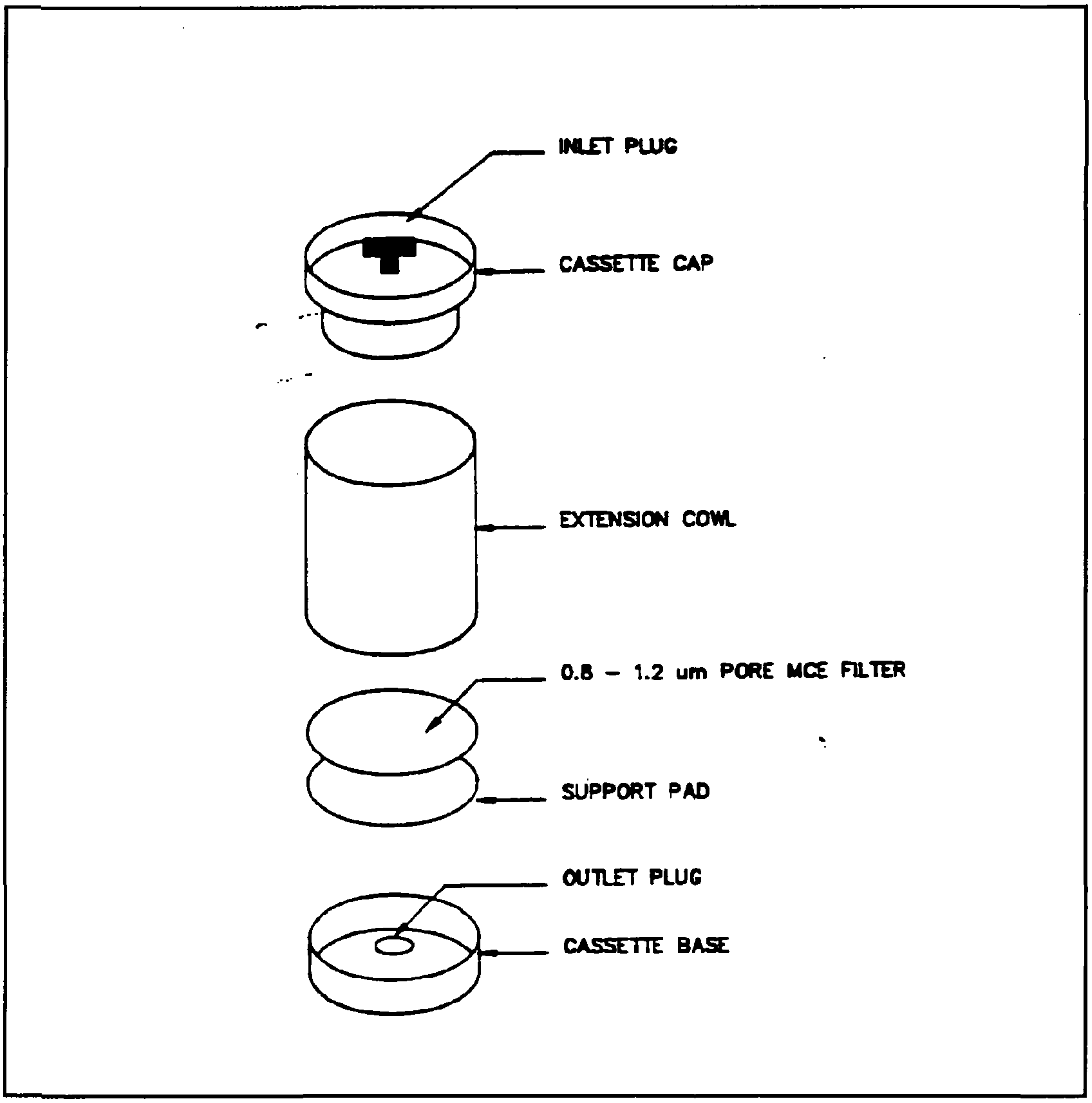
Figures

FIGURE 1. Transmission Electron Microscopy Filter Cassette



Figures

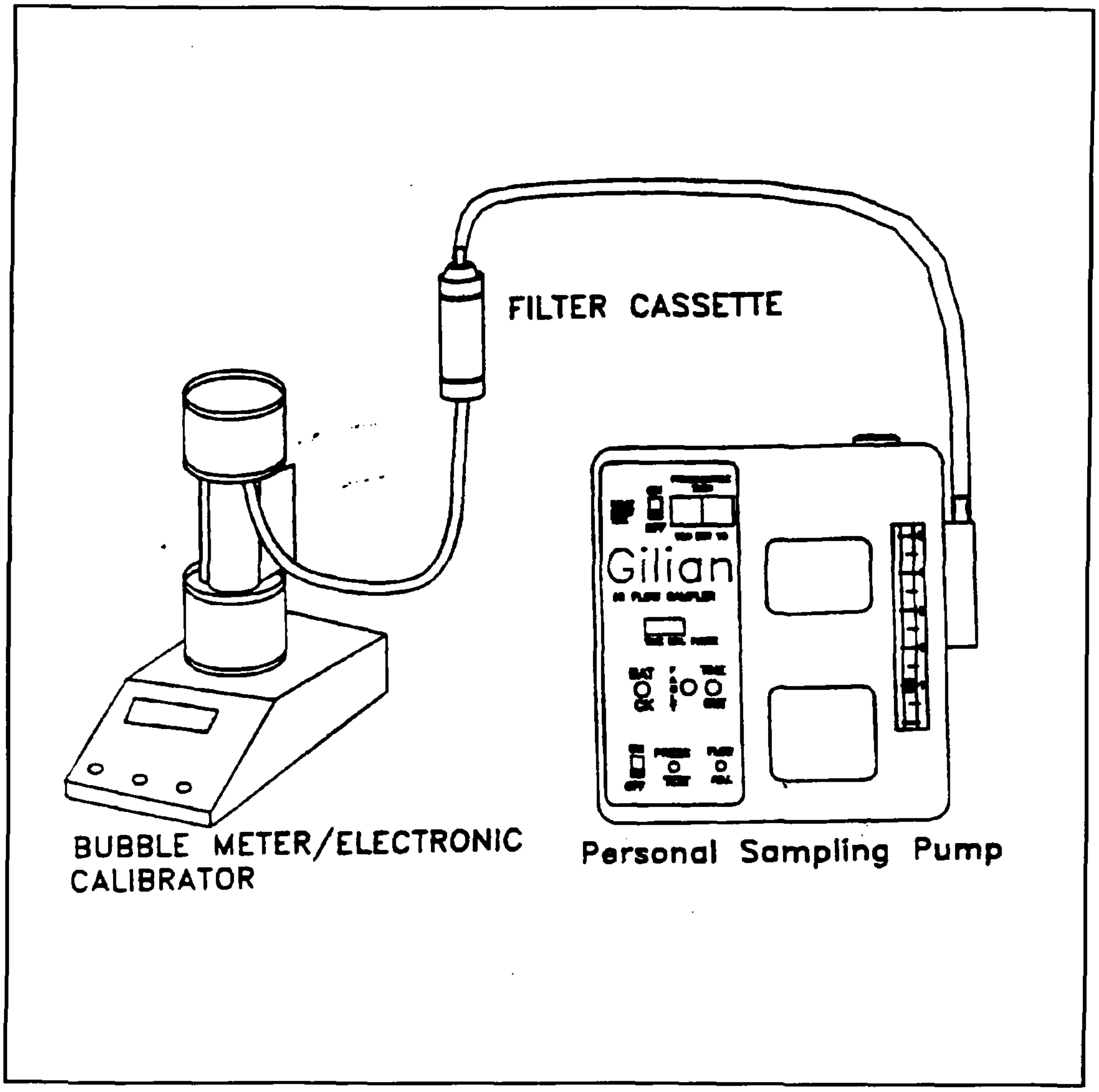
FIGURE 2. Phase Contrast Microscopy Filter Cassette



APPENDIX B (Cont'd)

Figures

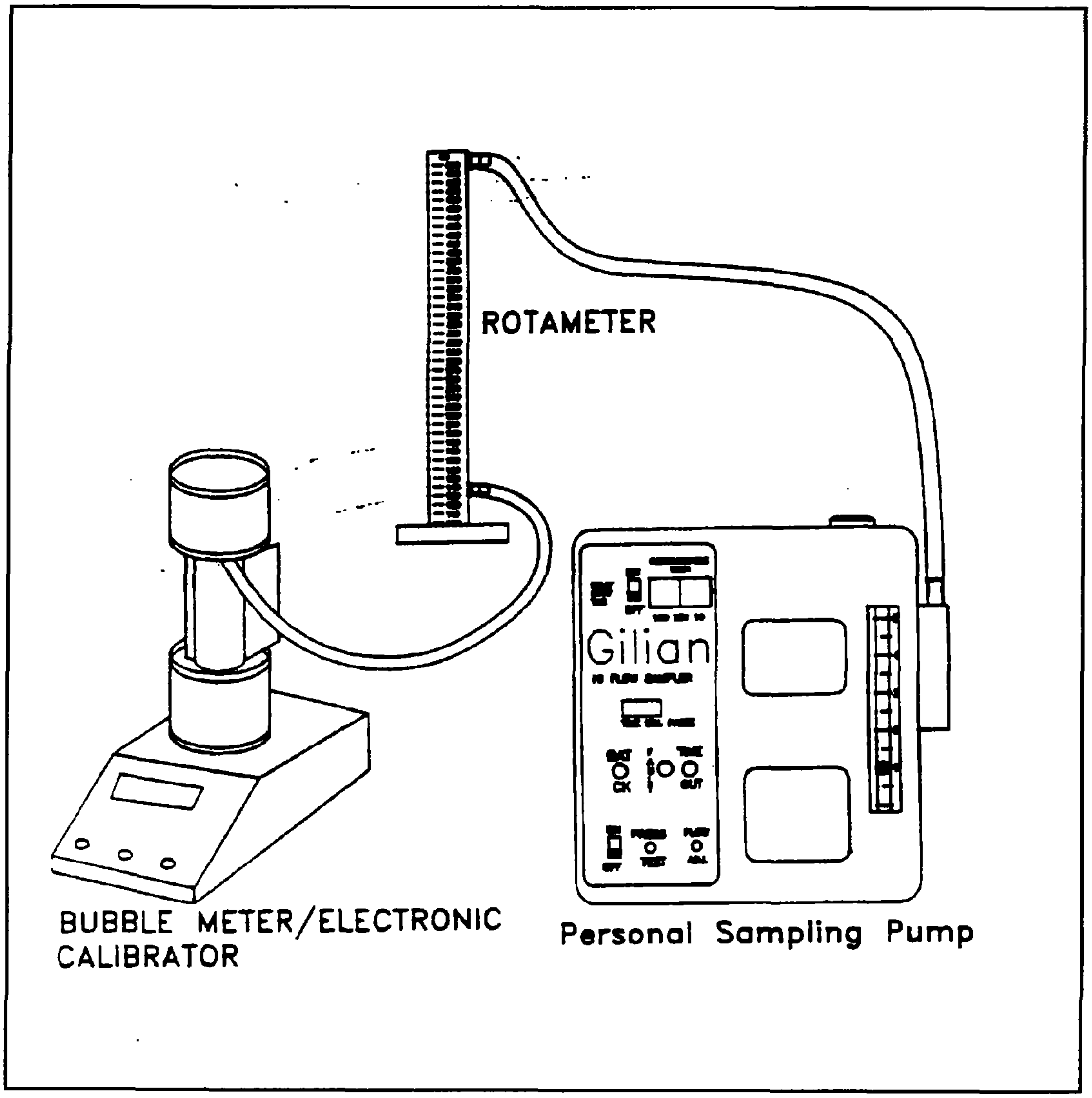
FIGURE 3. Calibrating a Personal Sampling Pump with a Bubble Meter



APPENDIX B (Cont'd)

Figures

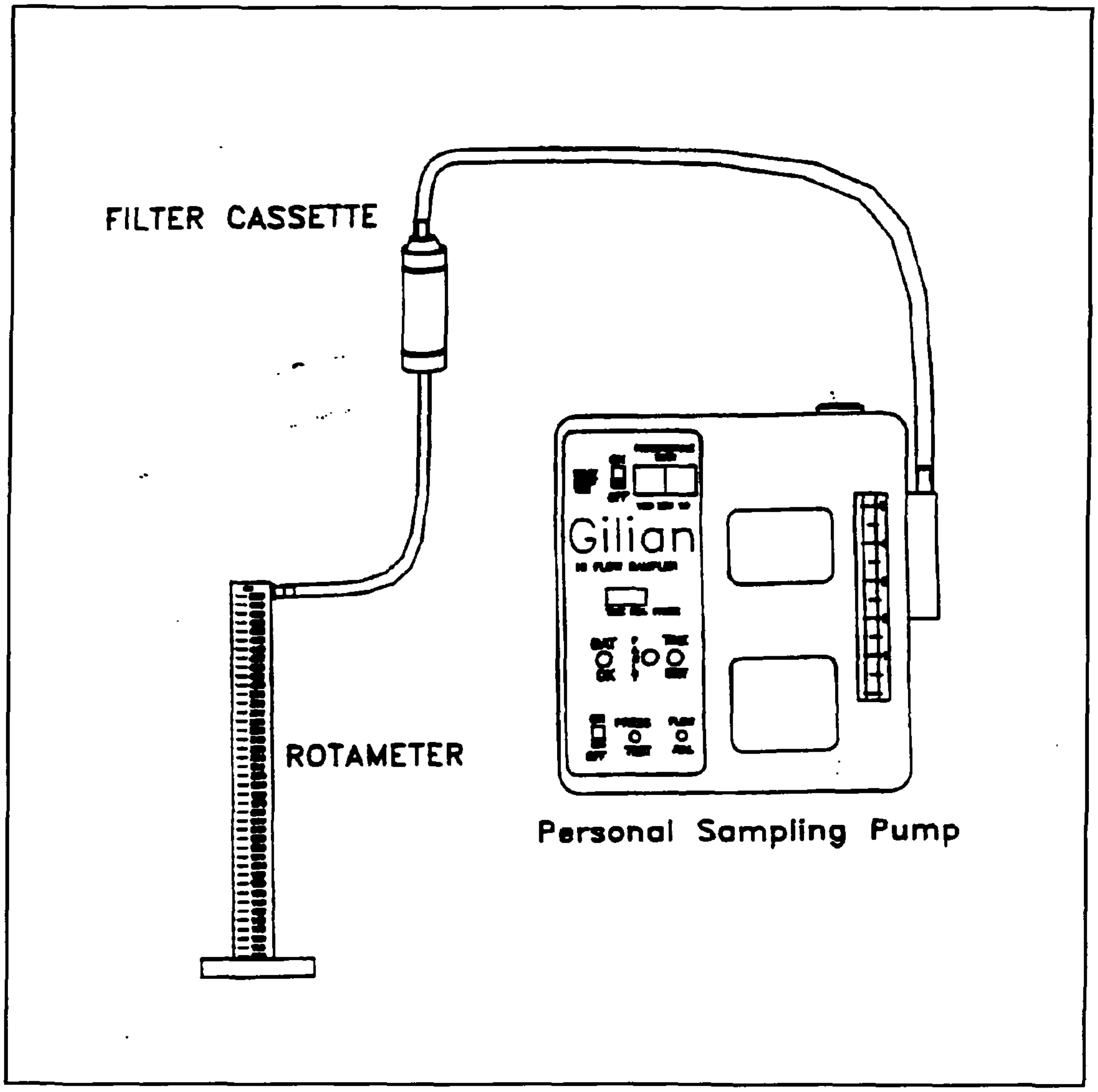
FIGURE 4. Calibrating a Rotameter with a Bubble Meter



APPENDIX B (Cont'd)

Figures

FIGURE 5. Calibrating a Sampling Pump with a Rotameter



APPENDIX B (Cont'd)

Figures

FIGURE 6. Personal Sampling Train for Asbestos

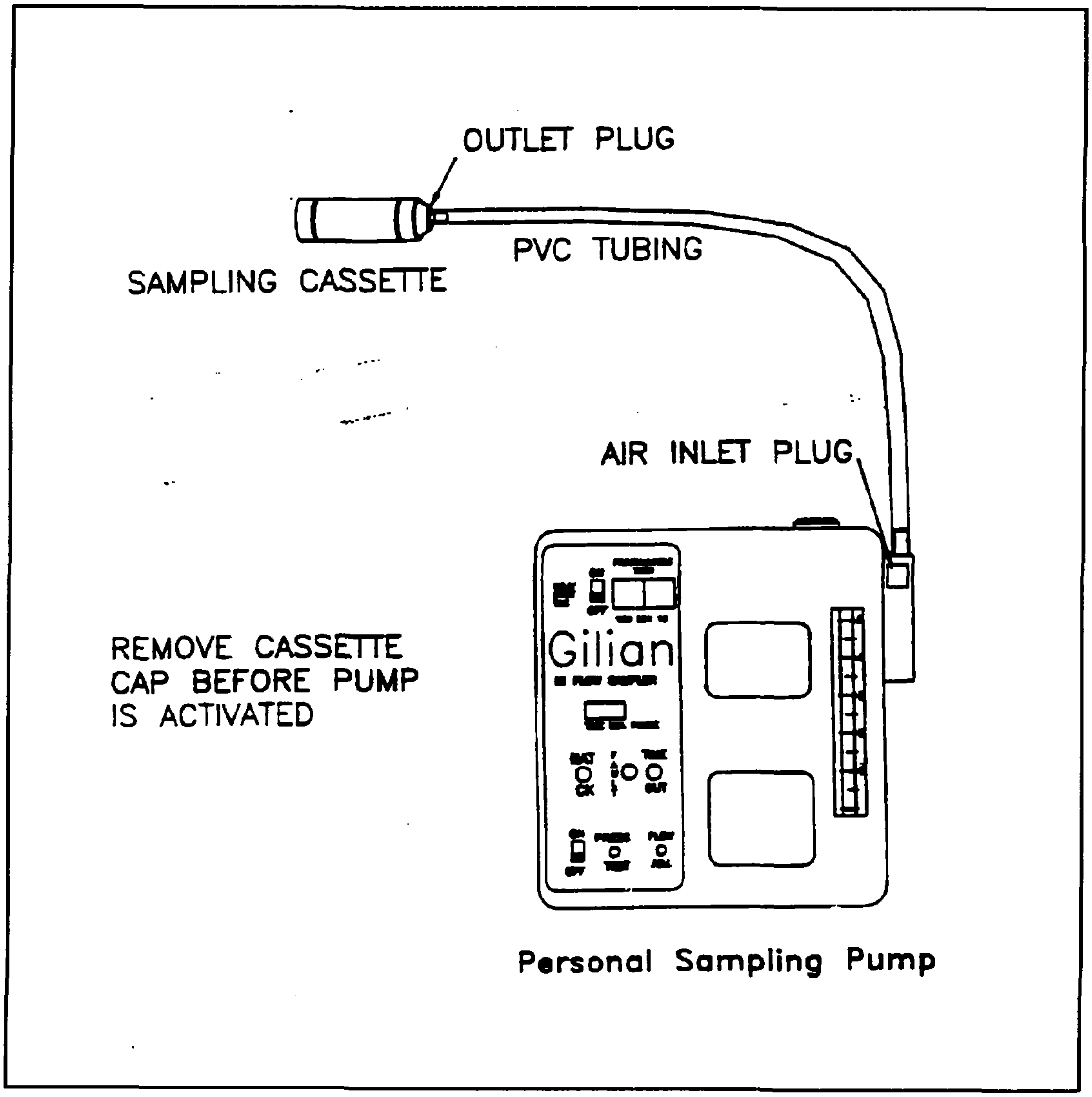
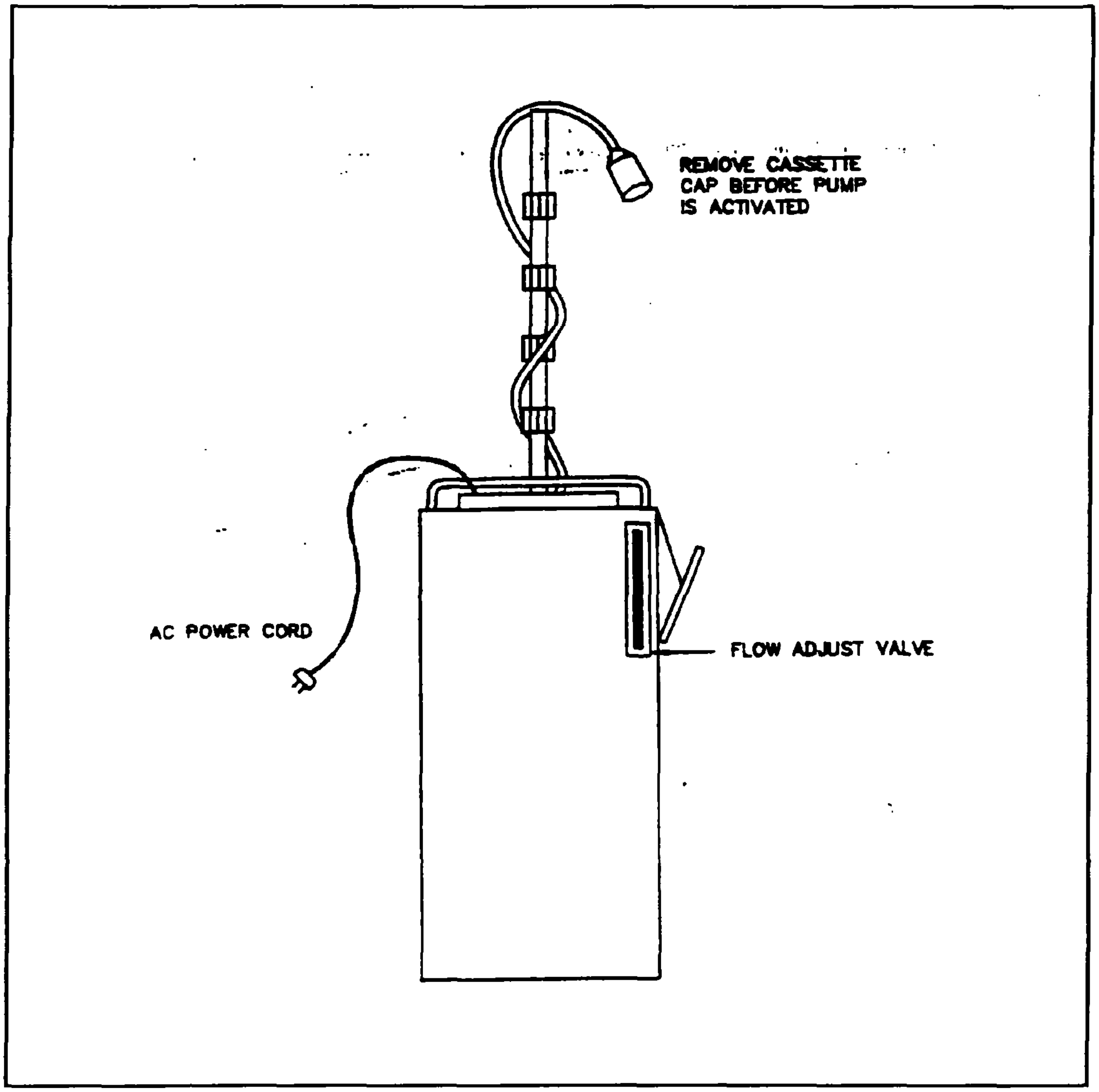


FIGURE 7. High Flow Sampling Train for Asbestos



ATTACHMENT C

Rotameter Calibration Data and Regression Analysis

Secondary Calibration of Zefon Rotometers

6/15/2005

Raw data used for regression lines:

Rotometei	Rotometer	DryCal
	5	5.022
	5.5	5.641
	6	6.261
	6.5	7.024
	7	7.545
	7.5	8.178
	8	8.56
	8.5	9.325
	9	9.877
	9.5	10.59
	9.75	10.74
	10	11.05
	10.25	11.31
	11	12.46
	11.5	13.09
	12	13.62
	12.5	14.19
	13.25	15.48
	14	16.69
	15.25	19.04
	16	20.88

Analysis

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.994505409
R Square	0.989041009
Adjusted R Squ	0.98846422
Standard Error	0.461803672
Observations	21

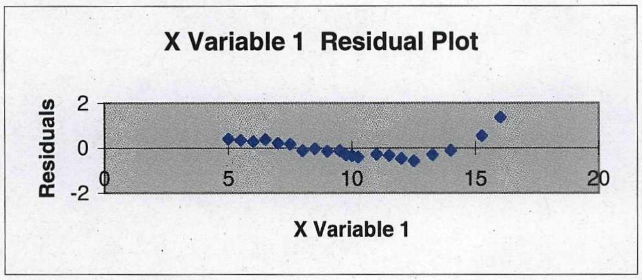
ANOVA

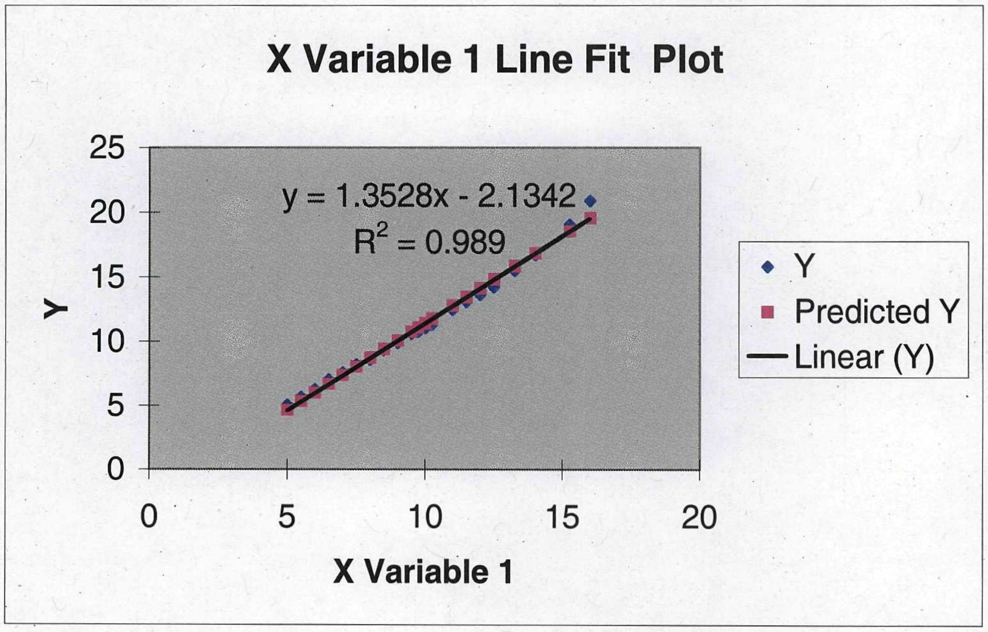
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	365.689167	365.689167	1714.736262	4.33347E-20
Residual	19	4.051989993	0.213262631		
Total	20	369.741157			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-2.134224023	0.338917396	-6.29718051	4.80517E-06	-2.843586284	-1.424861761	-2.843586284	-1.424861761
X Variable 1	1.352844733	0.032670012	41.40937408	4.33347E-20	1.284465613	1.421223853	1.284465613	1.421223853

RESIDUAL OUTPUT

Observation	*Predicted Y*	*Residuals*	*tandard Residuals*
1	4.629999643	0.392000357	0.870897971
2	5.306422009	0.334577991	0.743324051
3	5.982844376	0.278155624	0.617971806
4	6.659266742	0.364733258	0.810319298
5	7.335689109	0.209310891	0.465021083
6	8.012111475	0.165888525	0.368550632
7	8.688533842	-0.128533842	-0.285560612
8	9.364956208	-0.039956208	-0.088769768
9	10.04137857	-0.164378575	-0.365196012
10	10.71780094	-0.127800941	-0.283932345
11	11.05601212	-0.316012125	-0.702076702
12	11.39422331	-0.344223308	-0.764752824
13	11.73243449	-0.422434491	-0.93851277
14	12.74706804	-0.287068041	-0.637772313
15	13.42349041	-0.333490408	-0.740907792
16	14.09991277	-0.479912774	-1.066210919
17	14.77633514	-0.586335141	-1.302646987
18	15.79096869	-0.31096869	-0.690871823
19	16.80560224	-0.11560224	-0.256830777
20	18.49665816	0.543341843	1.20712979
21	19.51129171	1.368708294	3.040827013


X Variable 1 Residual Plot
Residuals
2
0
-2
0
5
10
15
20
X Variable 1


X Variable 1 Line Fit Plot
y = 1.3528x - 2.1342
R^2 = 0.989
Y
25
20
15
10
5
0
0
5
10
15
20
X Variable 1
Y
Predicted Y
Linear (Y)

Secondary Calibration of Zefon Rotometers

Calibrated on 08/17/05

Raw data used for regression lines:

Rotometer	Rotometer	DryCal
	5	5.08
	5.5	5.57
	6	6.08
	6.5	6.6
	7	6.91
	7.5	7.550
	8	7.99
	8.5	8.47
	9	8.85
	9.5	9.43
	9.75	9.6
	10	9.8
	10.25	10.14
	11	10.96
	11.5	11.37
	12	11.75
	12.5	12.19
	13.25	12.46
	14	13.45
	15.25	14.98
	16	15.61

Rotometer
RFW10377

DC-1 Flow Calibrator	Model	Serial No.
RFW07819	DC-1NC Rev. D	H 935

Analysis

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.99900712
R Square	0.99801523
Adjusted R S	0.99791077
Standard Err	0.13642638
Observations	21

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	177.818483	177.818483	9553.88861	3.8503E-27
Residual	19	0.353631	0.01861216		
Total	20	178.172114			

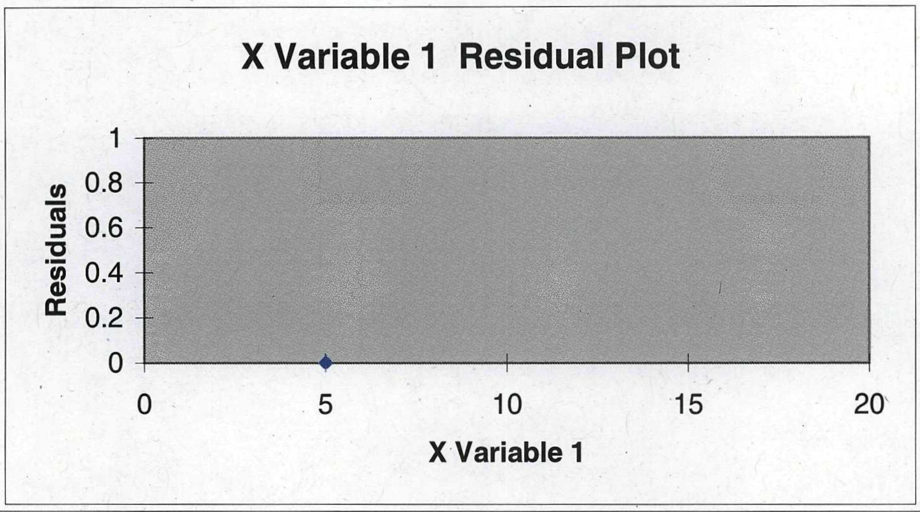
	Coefficients	*Standard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*
Intercept	0.41046711	0.10012323	4.09961923	0.00061028	0.20090679	0.62002744	0.20090679
X Variable 1	0.9433663	0.0096514	97.7439953	3.8503E-27	0.92316569	0.96356691	0.92316569

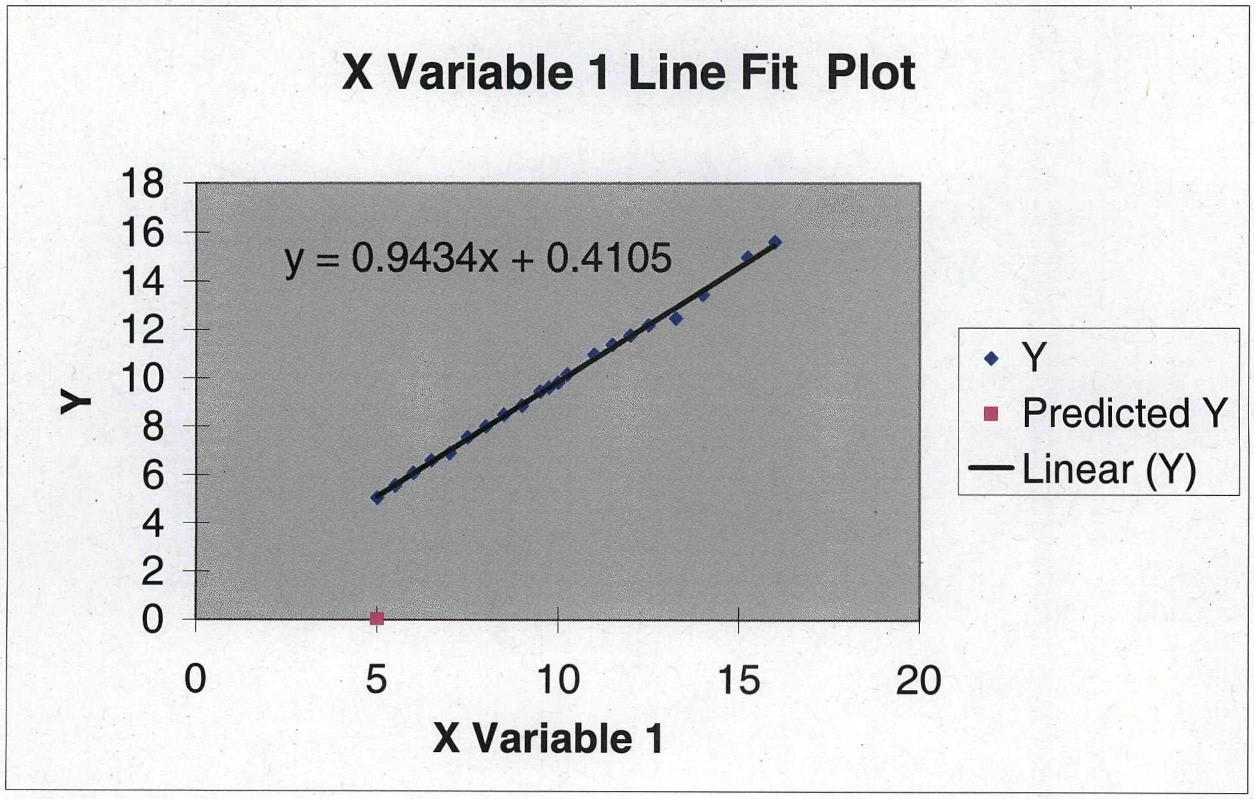
RESIDUAL OUTPUT

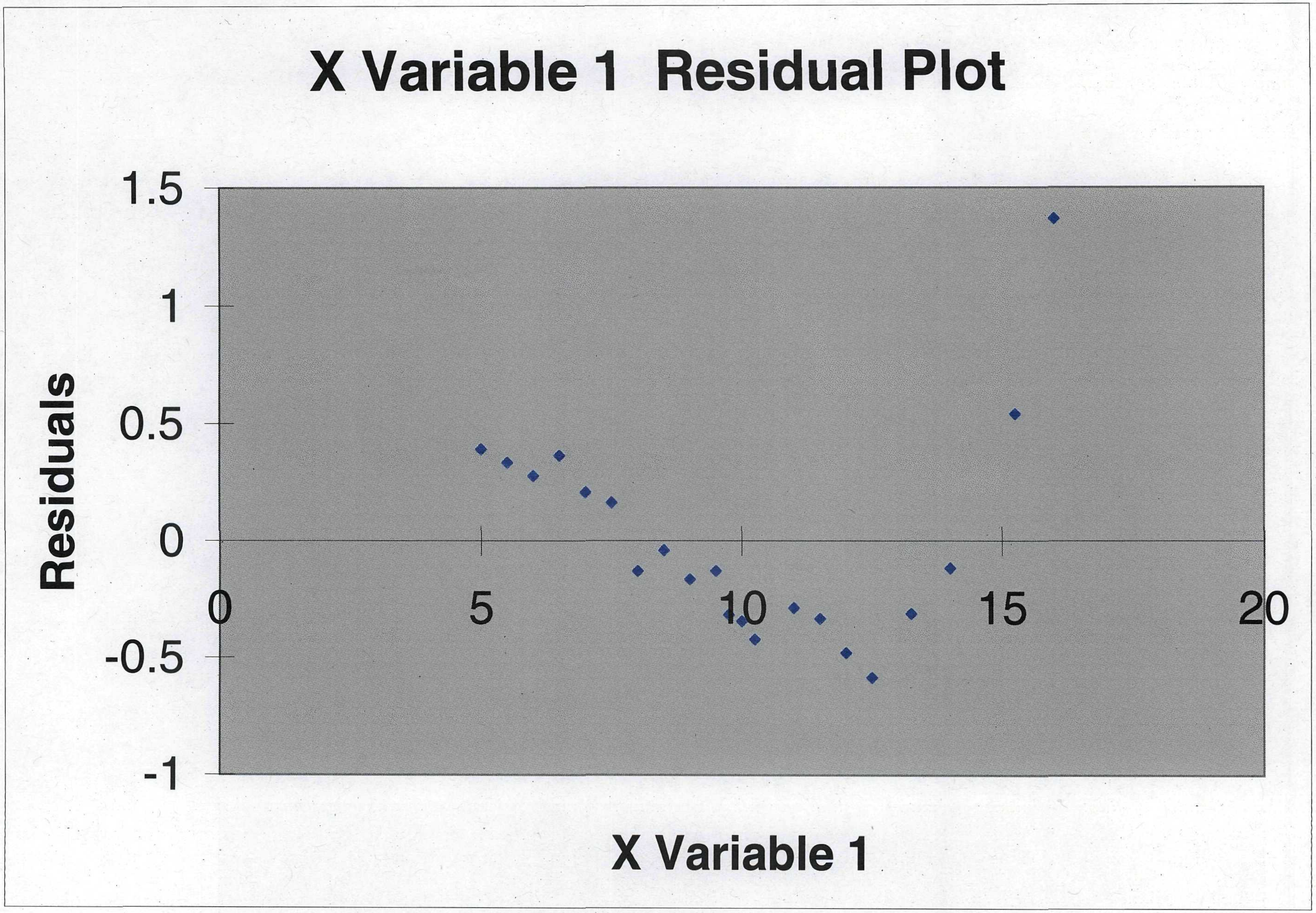
Observation	*Predicted Y*	*Residuals*	*ndard Residuals*
1	5.12729862	-0.0472986	-0.3557036
2	5.59898177	-0.0289818	-0.2179539
3	6.07066492	0.00933508	0.07020336
4	6.54234807	0.05765193	0.43356447
5	7.01403122	-0.1040312	-0.7823544
6	7.48571437	0.06428563	0.48345241
7	7.95739752	0.03260248	0.24518305
8	8.42908067	0.04091933	0.30772893
9	8.90076382	-0.0507638	-0.3817633
10	9.37244697	0.05755303	0.43282068
11	9.60828855	-0.0082885	-0.062333
12	9.84413012	-0.0441301	-0.3318753
13	10.0799717	0.0600283	0.45143568
14	10.7874964	0.17250357	1.29729258
15	11.2591796	0.11082042	0.83341179
16	11.7308627	0.01913727	0.14391959
17	12.2025459	-0.0125459	-0.0943498
18	12.9100706	-0.4500706	-3.3847023
19	13.6175953	-0.1675953	-1.2603807
20	14.7968032	0.18319679	1.37770966
21	15.5043279	0.10567207	0.7946942

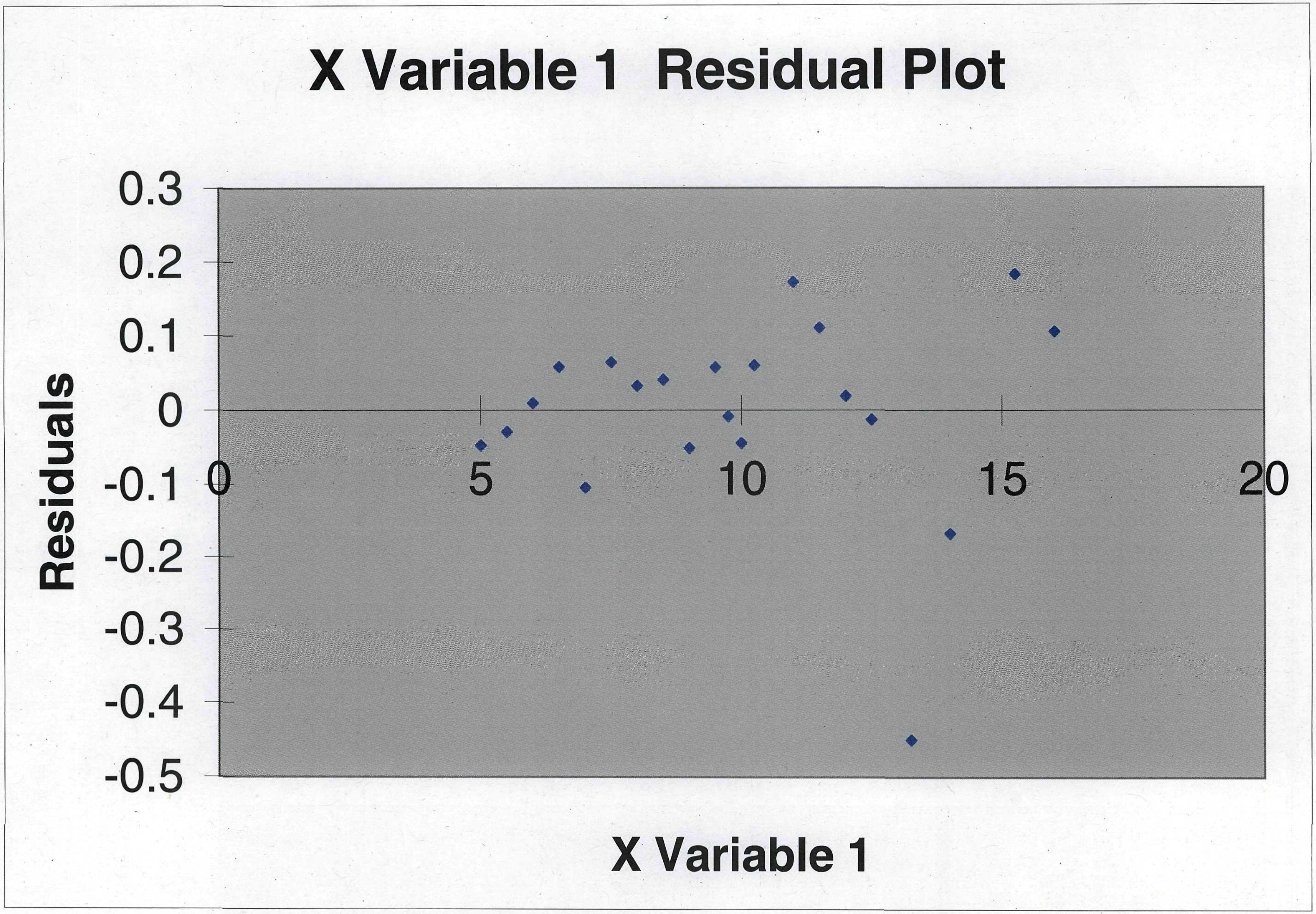
Upper 95.0%
0.62002744
0.96356691

Graph and Formula






X Variable 1 Residual Plot
1.5
1
0.5
0
-0.5
-1
Residuals
0
5
10
15
20
X Variable 1


X Variable 1 Residual Plot
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Residuals
0
5
10
15
20
X Variable 1

Raw Data

Secondary Calibration of Zefon Rotometers

Calibrated on 09/06/06

Raw data used for regression lines:

Rotometer #1	DryCal
5	3.84
5.5	4.623
6	5.05
6.5	5.67
7	6.01
7.5	6.760
8	7.66
8.5	8.417
9	9.02
9.5	9.75
9.75	9.99
10	10.41
10.25	10.82
11	12.55
11.5	13.67
12	14.68
12.5	14.8
13.25	16.21
14	17.81
15.25	19.55
16	19.66

Rotometer
RFW10377

DC-1 Flow Calibrator	**Model**	**Rental ID No.**
Pine Environmental	Dry-Cal DC-Lite	10960

Analysis

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.995823445
R Square	0.991664333
Adjusted R Sq	0.991225614
Standard Error	0.459699429
Observations	21

ANOVA

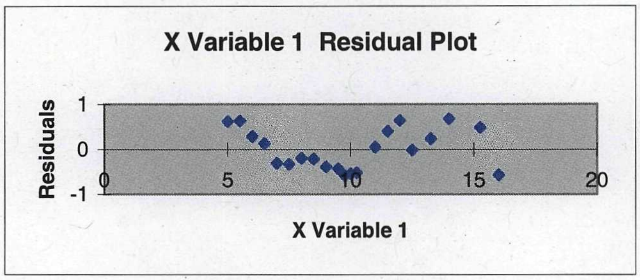
	df	SS	MS	F	Significance F
Regression	1	477.6676988	477.6676988	2260.361725	3.21683E-21
Residual	19	4.015147743	0.211323565		
Total	20	481.6828466			

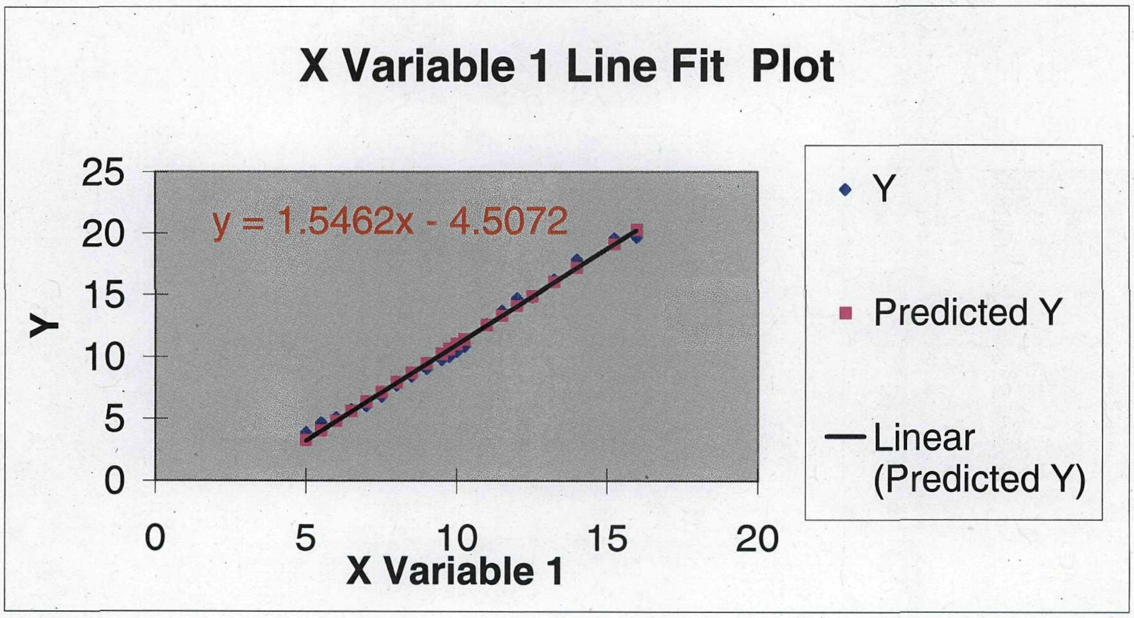
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-4.507218303	0.337373094	-13.35974438	4.1426E-11	-5.2133483	-3.8010883	-5.2133483	-3.8010883
X Variable 1	1.546161463	0.032521148	47.54326161	3.21683E-21	1.478093918	1.614229009	1.478093918	1.614229009

RESIDUAL OUTPUT

Observation	Predicted Y	Residuals	Standard Residuals
1	3.223589013	0.616410987	1.375734421
2	3.996669745	0.626330255	1.397872701
3	4.769750477	0.280249523	0.625473789
4	5.542831208	0.127168792	0.283821164
5	6.31591194	-0.30591194	-0.682748352
6	7.088992672	-0.328992672	-0.734260992
7	7.862073403	-0.202073403	-0.450996725
8	8.635154135	-0.218154135	-0.486886442
9	9.408234867	-0.388234867	-0.86648045
10	10.1813156	-0.431315598	-0.962630011
11	10.56785596	-0.577855964	-1.289685546
12	10.95439633	-0.54439633	-1.215008794
13	11.3409367	-0.520936696	-1.162650502
14	12.50055779	0.049442207	0.110347394
15	13.27363852	0.396361475	0.88461779
16	14.04671926	0.633280744	1.413385121
17	14.81979999	-0.019799988	-0.044190525
18	15.97942109	0.230578914	0.514616638
19	17.13904218	0.670957817	1.497474548
20	19.07174401	0.478255988	1.067393733
21	20.23136511	-0.57136511	-1.275198958

Graph


X Variable 1 Residual Plot
Residuals
1
0
-1
0
5
10
15
20
X Variable 1


X Variable 1 Line Fit Plot
y = 1.5462x - 4.5072
25
20
15
10
5
0
Y
0
5
10
15
20
X Variable 1
Y
Predicted Y
Linear (Predicted Y)

ATTACHMENT D

Example Air Sampling Forms